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AGRONOMIC EVALUATION TESTS ON MECHANICAL BLOCKING AND CROSS CULTIVATION OF SUGAR BEETS[1]

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INTRODUCTION

The problems involved in mechanical blocking and in cross cultivating sugar beets have occupied for some time the attention of sugar-beet agronomists, both in the United States and abroad. Mechanical blocking deals with the removal of a definite portion of the row to obviate either hand blocking with a hoe as a separate operation from hand thinning or the hand blocking commonly done in some sections by the thinner, by means of a short-handled hoe, just before the beets are thinned to leave a single plant in a place. It is therefore an operation which is applicable to row widths as now used and does not involve radical departure from the space allotment per plant now used in commercial practice.

With the development of the proposal to block sugar beets mechanically, there has arisen the desire to secure the added feature of the cultivating of the sugar beets throughout the season across the rows. For satisfactory cross cultivation, it is obvious that an adequate space must be provided in which the horses or tractor may travel in drawing the cultivator across the field. To meet this need, trials of a variety of beet spacings have been made by farmers and beet companies in which the row was reduced from the normal 20- to 22-inch width, a common practice being to reduce the row width to 18 inches and to block so as to leave the beets 18 inches apart, thus leaving the sugar beets in a square pattern.

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[1] Experimental work was conducted as follows: In the Sacramento delta area in California in cooperation with the California Agricultural Experiment Station; in northern Colorado in cooperation with the Colorado Agricultural Experiment Station; in Minnesota in cooperation with the Minnesota Agricultural Experiment Station; in Idaho in cooperation with the Amalgamated Sugar Co.; in Utah in cooperation with the Utah-Idaho Sugar Co.; in southern California in cooperation with the American Beet Sugar Co.; in the Arkansas Valley, Colo., in cooperation with the American Beet Sugar Co. Acknowledgment is due G. H. Coons, principal pathologist, Division of Sugar Plant Investigations, U.S. Department of Agriculture, for much assistance in the preparation of this manuscript.

This circular deals principally with the agronomic results obtained in the mechanical-blocking and cross-cultivating-of-beets project, which has been studied from the point of view of both the agricultural engineer and the agronomist. The agricultural engineer's task has been the development and testing of equipment that will do a satisfactory job of removing beets in the row, leaving blocks of seedlings in satisfactory condition for hand thinning. This work has been briefly summarized and reported elsewhere (*8*).[2] The agronomist is concerned with the evaluation of the results obtained after such modification of crop handling, since these modifications may affect the yield and quality of the crop. This circular reports the effects of replacing hand blocking by mechanical blocking in fields where the sugar beets were planted in rows 20 to 22 inches wide, and reports also experiments in which sugar beets were cross blocked so that cross cultivation later in the season was possible.

Previous investigations have been made on this subject. Mechanical blocking has been tried in Europe on some of the larger estates where sugar-beet stands were sufficiently good to permit this practice. In a preliminary report on this project, the European experience, which was not altogether satisfactory, has been briefly reviewed (*10*). Numerous experiments have been conducted in the United States on cross blocking of sugar beets mechanically to determine the advantages and disadvantages of this method. Nuckols (*9*) carried on experiments in Utah which demonstrated that the method was feasible provided stands were good, and he pointed out some of the advantages likely to accrue. Immer (*4*) emphasized the relationship between space allotment and resulting tonnage. Lund (*6*) enumerated the added benefits resulting from cross cultivation of sugar beets as compared with mechanical blocking alone. Mervine (*7*) discussed the problems involved in mechanical cross blocking of beets, indicating the equipment required to meet different field conditions as to stand. Description of adapted cultivators for use in cross blocking and cross cultivating of beets is found in a leaflet published recently on this subject (*8*).

There is need for reducing the amount of hand labor involved in the growing of sugar beets. Studies by the Colorado Agricultural Experiment Station (*2*) show that the costs due to hand labor represented in 1929 approximately two thirds of the cash outlay of the beet grower, and that the total labor costs represent approximately 40 percent of the gross costs of growing beets. The peak loads for labor come in the spring at blocking time and in the fall at harvest time. Progress is being made in the development of machines for harvesting sugar beets. Such machines will reduce greatly the amount of hand labor to be employed in the fall. In such an eventuality, mechanization wherever possible of spring operations would become even more important, in order that the labor demand in sugar-beet growing be balanced and not abnormally large in one portion of the growing season.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 21.

THE MECHANICAL BLOCKING OPERATION

There are several essential requirements which a cross-blocking machine must fulfill. The equipment should be readily available on the average farm where sugar beets are grown, its cost, including the extra cultivating tools, should be low, and it should be of a type that can be easily adapted to meet special conditions. In order to replace present methods, the machine must block beets more cheaply than can be done with the hand hoe, producing equal or superior results. Taking into consideration the diversity of soil and plant-growth conditions to be found in the various beet-growing districts of the United States, widespread use of machine equipment would depend on its adaptability to meet these conditions. In performing the job of blocking, the portions removed must be cut cleanly, weeds must be removed effectively, and the plants that are left in blocks between the cut-out spaces must not be dislodged but must be left so that the subsequent thinning operation can be more rapidly performed.

Field trials with a considerable variety of equipment indicated that the standard beet cultivator equipped with suitable cultivating tools would do a satisfactory job if the tools were chosen and adjusted to the particular work to be done. In practice, the cultivator with the cutting tools (duckfeet or sweeps), and with the attachments for protecting the blocks to be left (shields or disks), is drawn across the field at right angles to the rows, thus cutting out surplus sections of the row and leaving small blocks that are subsequently thinned by hand. It was found that in loose peat soils, such as those of the delta section in California, ordinary knives and sweeps became clogged, although the same equipment would block sugar beets satisfactorily in firmer soils. Each soil type and soil texture calls for trial and adjustment to secure the most effective arrangement (figs. 1 and 2).

After tools have been found that will work efficiently and the general set-up of these tools has been determined, the ratio of the size of block to be left to that to be cut out must be determined. This must be based upon the actual stand of beets in the field, and it was found that care in this regard was extremely important. By gaging the size of the portion cut out in correct proportion to the block to be left, the desired number of beets per hundred feet of row as a final stand can be most nearly attained.

As a means of arriving at this end, the results of field experiments are directly applicable. In a number of fields the initial stand of beets was determined. Plots were so arranged in these fields that cross-blocked plots alternated with hand-blocked plots. The number of blocks left by the machine set to cut out different widths and the number of beets left by the thinners as final stand were found, and these final results were contrasted with the number of beets left as final stand in standard hand operations.

From these data it was possible to construct a chart consisting of a series of curves which shows with a given initial stand the proper proportions between the cut-out portion of the row and the portion left to secure a desired number of beets per 100 feet of row after thinning. The resulting stand of beets as indicated on this chart (fig. 3) takes into consideration not only the probability of the mechanical blocker cutting out an occasional beet, but makes allowance for beets lost in the thinning operation. Therefore, when the percentage stand is known before blocking, it is possible to adjust the equipment on the cultivator to compensate for stand.

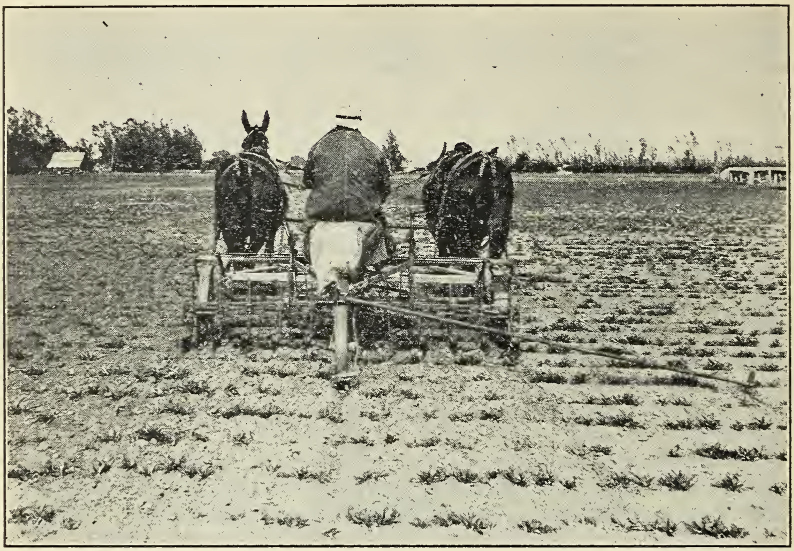

FIGURE 1.—A beet cultivator equipped with 12-inch adjustable weeder knives for cross blocking a field of sugar beets in southern California.

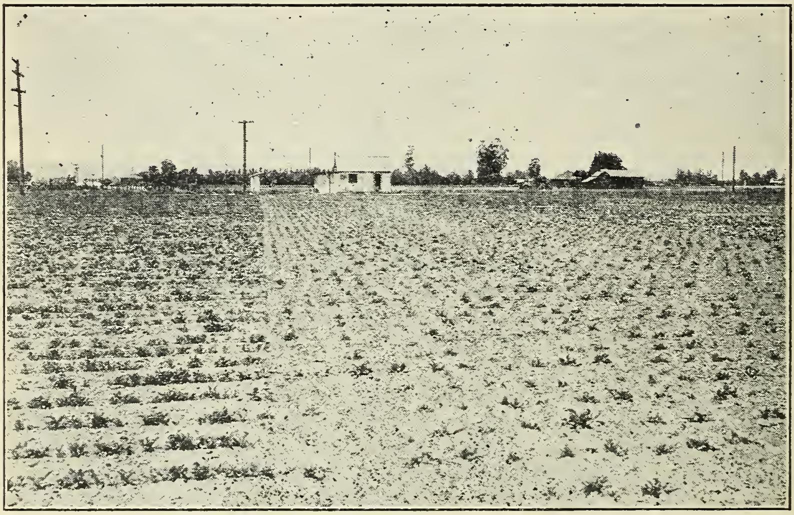

FIGURE 2.—A field of sugar beets cross blocked with the beet cultivator equipment shown in figure 1. Several alternate comparison strips left in the field for study of the mechanical cross-blocking and the hand-blocking methods are shown.

To illustrate the use of figure 3, suppose there are 50 inches per 100 inches of row in which there are beets. Find the line marked 50 at the bottom of the chart and follow it to its intersection with the curve marked 4–8. At the left of the chart opposite this point it will be noted that the final stand of beets after thinning will be 85 beets per 100 feet of row. This means that with the knives set so as to leave a 4-inch block and cut out 8 inches, beets would be left in 85 percent of the blocks. With the same stand of beets before thinning, a 4–7 combination would produce a stand of 93 percent. The final stand of beets as indicated on the left of the chart takes into consideration not only the probability of the mechanical blocker cutting out an occasional block of beets but also allows for beets lost in the thinning operation.

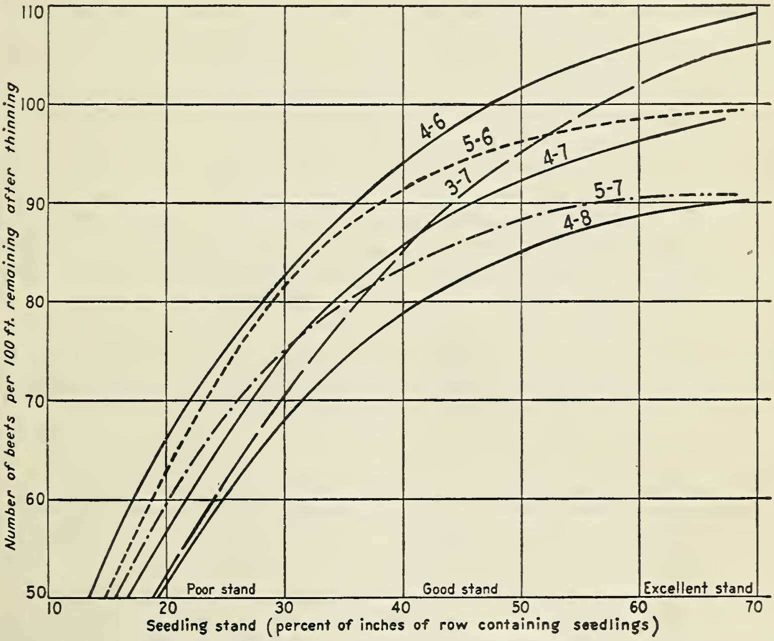

FIGURE 3.—Chart for determining the proper spacing of tools on the cultivator for cross blocking sugar beets when the stand of seedlings is known.

Results of the trials have shown, that, for all but the extremely loose-textured soils, fairly good initial stands that are of reasonable uniformity can be blocked mechanically and with results in the final stand that approximate those from careful hand blocking.

Records were kept of the hours of labor required to thin beets following each method of blocking. It was found that on the average 25.6 man-hours were required for thinning 1 acre of beets when mechanically cross blocked as compared to 41.41 man-hours when the beets were hand blocked. There is therefore a marked saving in labor costs for the subsequent thinning operation, a saving that may be placed conservatively at 30 to 40 percent.

AGRONOMIC EXPERIMENTS

TESTS IN FARMERS' FIELDS

By means of a number of experiments carried on in farmers' fields during 1931 and 1932, comparisons between the results from mechanically blocking beets and standard hand blocking were obtained. The experiments in 1931 were carried on in California, Colorado, and Nebraska. In 1932, similar experiments were conducted in Idaho, Utah, and Colorado. The comparisons obtained cover a wide range of soil types and variations in plant-growth conditions. The plan followed in these tests in which mechanical and hand blocking were contrasted was to block sugar beets in strips across the field, alternating the type of blocking used. Data for the two treatments were taken from paired plots, adjacent areas of similar size being compared.

The beet fields selected for experiments had for the greater part satisfactory initial stands of beets, making it possible to employ cultivator equipment of the type illustrated, so set that from 7 to 9 inches of the beet row were removed for each foot of row, and a block varying from 5 to 3 inches in length was retained. The spacing of the knives was made either by reference to the chart, or by judgment, so that the final stands resulting would as nearly as possible correspond to the number of sugar beets per hundred feet being obtained by the hand-blocking method.

Stand counts and actual yields of the comparison plots of the two types of blocking were taken. In addition, sucrose and apparent coefficient of purity determinations were made from composite samples of 10 or 20 beets each, at least 1 sample being taken from each plot. In most of the experimental tests several samples were taken from each plot, and the results averaged. The analytical methods used in these determinations were essentially those outlined on page 10.

The results of the 1931 and 1932 experiments are summarized in table 1. In this table the number of paired comparisons obtained is shown. The data have been analyzed according to Student's method as modified by Love (*5*) and odds of significance determined. Odds of 30 to 1 have been taken as a minimum level of significance.

From table 1 it is seen that in 1931 in 3 of the fields (1, 3, and 4) the stand[3] after thinning resulting from the 2 methods of blocking did not differ significantly. In three fields (2, 5, and 7) hand blocking gave a significantly superior stand. In one field mechanical blocking gave a significantly better stand than hand blocking. The conditions in a field at the time work is done, the quality of the blocking given, and the general care taken to maintain the stand greatly influence the final results. Considering the experiments as a whole, no significant superiority of one method over the other is demonstrated. It should be pointed out that the trend seems to indicate that stands may be expected to range lower with mechanical blocking than those obtained with hand blocking. Since in hand blocking the workman may compensate in his blocking for skips in the row, it is to be expected that more beets will be left. The question is whether these beets not uniformly spaced will so efficiently utilize the soil spaces as to influence the yield commensurate with the increased number.

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[3] In commercial practice, 100 beets in 100 feet of row are considered as 100-percent stand. This criterion has been followed in the results reported in this circular.

TABLE 1.—*Comparison in farmers' fields of hand blocking and mechanical blocking of sugar beets, 1931–32*

1931

Location	Field no.	Type of blocking	Comparisons	Final stand[1]	Yield of beets per acre	Sucrose	Apparent coefficient of purity	Calculated sugar yield per acre[2]	
								Gross	Indicated available
			Number	*Percent*	*Tons*	*Percent*		*Lb.*	*Lb.*
Woodland, Calif	1	Mechanical	40	87.2	23.03	14.87	--------	6,849	-------
		Hand	40	93.6	21.46	15.28	--------	6,558	-------
		Approximate odds	------	16:1	76:1	6:1	--------	24:1	-------
Fort Collins, Colo	2	Mechanical	18	90.9	19.97	15.50	90.60	6,191	5,609
		Hand	18	97.4	19.74	15.80	89.60	6,238	5,589
		Approximate odds	------	(3)	5:1	4:1	17:1	1:1	2:1
	3	Mechanical	12	93.0	20.16	14.08	87.80	5,677	4,984
		Hand	12	96.9	20.32	14.05	88.20	5,710	5,036
		Approximate odds	------	11:1	3:1	1:1	3:1	1:1	1:1
	4	Mechanical	6	105.4	14.70	16.70	94.00	4,910	4,615
		Hand	6	100.0	15.37	16.20	93.50	4,980	4,656
		Approximate odds	------	9:1	11:1	7:1	3:1	2:1	2:1
	5	Mechanical	5	75.3	15.51	12.50	83.40	3,887	3.247
		Hand	5	92.3	14.55	11.90	83.00	3,457	2,878
		Approximate odds	------	(3)	22:1	7:1	2:1	23:1	25:1
Rocky Ford, Colo	6	Mechanical	6	90.5	13.17	20.71	88.45	5,455	4,825
		Hand	6	85.2	12.47	20.83	88.73	5,195	4,610
		Approximate odds	------	30:1	17:1	2:1	2:1	10:1	14:1
Scottsbluff, Nebr	7	Mechanical	4	64.2	18.16	16.60	90.36	6,029	5,448
		Hand	4	74.9	17.49	16.67	90.99	5,831	5,306
		Approximate odds	------	32:1	13:1	3:1	5:1	12:1	10:1
Summary of results (average of averages)	-----	Mechanical	7	86.64	17.81	15.85	[4] 89.10	5,571	[4] 4,788
		Hand	7	91.47	17 34	15.82	[4] 89.00	5,424	[4] 4,679
		Approximate odds	------	11:1	18:1	7:1	2:1	28:1	11:1

1932

Location	Field no.	Type of blocking	Comparisons	Final stand[1]	Yield of beets per acre	Sucrose	Apparent coefficient of purity	Calculated sugar yield per acre[2]	
								Gross	Indicated available
Twin Falls, Idaho	1	Mechanical	10	79.5	12.20	16.91	84.78	4,125	3,497
		Hand	10	89.5	14.72	16.76	84.94	4,934	4,191
		Approximate odds	------	49:1	157:1	2:1	2:1	81:1	40:1
Blackfoot, Idaho	2	Mechanical	10	93.5	17.43	17.02	88.56	5,934	5,255
		Hand	10	117.0	15.51	16.59	89.03	5,147	4,582
		Approximate odds	------	(3)	37:1	15:1	2:1	216:1	74:1
Aberdeen, Idaho	3	Mechanical	10	93.0	21.13	18.48	90.29	7,810	7,052
		Hand	10	109.5	22.04	18.45	89.62	8,134	7,290
		Approximate odds	------	295:1	5:1	1:1	5:1	6:1	4:1
Garland, Utah	4	Mechanical	10	90.0	16.14	14.38	82.37	4,640	3,820
		Hand	10	86.0	16.04	14.60	82.95	4,680	3,875
		Approximate odds	------	1:1	1:1	3:1	2:1	1:1	2:1
Fort Collins, Colo	5	Mechanical	8	92.1	13.82	16.03	87.20	4,371	3,814
		Hand	8	91.5	12.95	16.19	86.90	4,186	3,645
		Approximate odds	------	12:1	48:1	3:1	2:1	7:1	8:1
Summary of results (average of averages)	-----	Mechanical	5	89.6	16.14	16.56	86.64	5,376	4,688
		Hand	5	98.7	16.25	16.52	86.69	5,416	4,717
		Approximate odds	------	12:1	1:1	2:1	1:1	2:1	1:1

[1] Percentage based on a standard of 100 beets in 100 feet of row.

[2] Obtained by multiplying yield by sucrose percentage and averaging individual plot values for sugar production, hence differ slightly from product of means given in this table.

[3] Odds are very great.

[4] Average of 6 comparisons.

This question is partially answered by the actual yields obtained in these comparison plots. In the 1931 experiments, significant yield differences were obtained in only one experimental field (1) and these were decisively in favor of the mechanically blocked plots. In all the other fields, including those in which final stands were significantly in favor of hand blocking, the yields were not significantly different. Considering the actual yields from the seven experiments as a whole, the difference in the average of averages was only 0.47 ton, and this was not large enough to be significant. Similarly, in quality of the sugar beets and in the calculated values for sugar produced per acre, no significant differences appeared. No evidence was found in the 1931 tests to indicate in general that mechanical blocking reduced yields of beets or of sugar.

The results from the 1932 experiments in many respects parallel those of 1931. In two fields (4 and 5) the stands obtained by the two methods contrasted were not significantly different. In three fields (1, 2, and 3) the stand obtained by hand blocking was significantly better. The general tendency for better stands from hand blocking was evident in 1932 as in 1931. The analysis of the five experiments as a whole does not reveal general superiority in respect to stand of hand blocking, however.

The yields in 1932 were not consistently in favor of one method or the other. In one field (1) the yields from the hand-blocked plots were significantly higher; in two fields (2 and 5) the yields were significantly in favor of the mechanically blocked plots. The other two fields (3 and 4) did not show significant differences. Taking the average of the five experiments no significant difference between the two methods in regard to yield is shown.

No significant differences in quality of the beets produced were found. The calculated values for sugar produced per acre therefore reflect largely the effect of beet yield, and although the sugar yield is significantly different in two cases, it cannot safely be assigned as indicating that one method is superior to the other.

CROSS-CULTIVATION TESTS IN 1931

Preliminary experiments to ascertain results obtainable in cross cultivating beets were conducted in 1931. In the test at Fort Collins, Colo. (table 2, field 1), the plots were arranged in a systematic manner, replicated five times, and all of the cultivations were done with a horse-drawn cultivator. In the test at Scottsbluff, Nebr. (field 2), the plots were arranged in four randomized blocks, and cultivations lengthwise of the row were made with a horse-drawn cultivator, while those across the row were made with a hand cultivator. The plots were 12 feet wide and 132 feet long in the first field and 17 feet wide and 47 feet long in the second field. Yield data were obtained on an actual basis by harvesting all of the beets from the inner rows and computing to an acre basis. For determining percentage of sucrose and apparent coefficient of purity, three 20-beet samples of normally competitive beets were harvested from each plot in field 1. In field 2, beet samples were taken at random, 10-beet samples being taken for percentage of sucrose determination for each type of cultivation contrasted, and purity determinations were obtained from approximately three fourths of these samples. The average values obtained are given in table 2.

TABLE 2.—*Results obtained from comparisons of normal cultivating and cross cultivating of beets at Fort Collins, Colo., and Scottsbluff, Nebr., 1931*

Location	Field no.	Space allotment	Cross cultivations	Comparisons	Final stand[1]	Yield of beets	Sucrose	Apparent coefficient of purity	Calculated sugar yield per acre[2]	
									Gross	Indicated available
		Inches	*Number*	*Number*	*Percent*	*Tons*	*Percent*		*Pounds*	*Pounds*
Fort Collins, Colo	1	16 by 20	0	5	83.8	15.76	12.50	83.3	3,933	3,280
		do	1	5	83.0	15.90	12.50	83.6	3,988	3.339
		do	2	5	82.2	15.70	11.80	82.5	3,705	3,068
		do	3	5	85.5	15.27	12.10	83.2	3,702	3,089
Difference required for significance.[3]					3.90	2.07	.91	2.72	653	625
Scottsbluff, Nebr.[4]	2	12 by 20	0	4	64.2	18.16	16.60	90.4	5,831	5,449
		do	1	4	65.6	18.40	16.18	90.6	5,961	5,401
		do	2	4	65.5	20.03	16.29	90.4	6,528	5,901
Difference required for significance.[3]					7.04	1.72	.55	.84	570	547

[1] Percentage based on a standard of 100 beets in 100 feet of row.

[2] Obtained by multiplying yield by sucrose percentage, and averaging individual plot values for sugar production; hence differ slightly from product of means given in this table.

[3] Obtained by calculating the generalized standard error of the experiment, multiplying by the $\sqrt{2}$ to determine the standard error of the difference. This value is then multiplied by 2 to obtain the amount required for significance. Any difference between treatment greater than this value is considered significant.

[4] Analysis of variance method (*3*) used for reduction and analysis of these data.

Analysis of the data obtained for these two tests indicates that the initial stands in the case of each experiment were not significantly different, hence opportunity for fair comparison was given. In field 1 weeds were not a factor. Statistically significant differences were not obtained for the variables studied. In this field cross cultivations apparently did not benefit the crop. In field 2 weeds were a factor and a different picture is presented. Here, the two cross cultivations which gave more effective weed control produced sharp and statistically significant increase in yield of beets over what was obtained from plots not cultivated or receiving only one cross cultivation. The significant increase shown in sugar production was due to the larger beet yield, since the quality of the beets in the different treatments did not differ significantly. The preliminary experiments of 1931 indicated that response to cross cultivations was conditioned by the importance of the weed factor, and that the cultivations themselves did not strongly influence yield or quality.

From the 2 years of experimentation and in line with wide observation in a number of field trials of mechanical blocking, it seems safe to conclude that with reasonable care mechanical blocking is feasible when performed on firm soils free from surface crust and with adequate initial stands. The resulting final stands may in some cases be less from mechanical blocking than from hand blocking. In general, the differences are small and from the tests seem largely, if not entirely, compensated for by the increased weight of the more uniformly spaced sugar beets that results from the mechanical blocking. It would seem safe to attribute the general absence of significant yield differences from the two types of blocking to such compensation. The similarity in sucrose and purity results, and in sugar production, from the two methods is to be expected, if the methods give approximately the same final results in yield, with stands being only slightly different. The practice seems safe for general use with adequate stands, if due precautions are taken in adjusting the cultivator for the purpose.

MECHANICAL-BLOCKING AND CROSS-CULTIVATION TESTS IN 1932

In order to evaluate the effects resulting from the mechanical handling of the crop in the manner previously described, eight tests consisting of many-time replicated plots were carried on in 1932 at the following places: Grand Forks and Waseca, Minn.; Scottsbluff, Nebr.; Fort Collins and Rocky Ford, Colo.; Sandy, Utah; Twin Falls, Idaho; and Chino, Calif.

The plan followed in all experiments was essentially the same. Small plots (50 to 75 feet in length, 7 or more feet wide) arranged in five randomized blocks (*3*) were used for each of the variables listed. Planting rate, date of planting, care of plots, and other factors conformed to good agricultural practice for each area in which the individual tests were performed. A tape was used in most cases to insure greater uniformity in spacing the beets in the hand-blocked beet plots. The mechanical operations were generally performed by garden tractor-drawn cultivator equipment, or else by wheel hoes, and approximated in general the results obtainable with field equipment. The operations in the small plots were less efficient and in some cases stand losses not to be expected in field operations occurred.

Data presented herewith were taken in 7 of the 8 tests [4] from beets that were normally competitive [5] for the conditions of the particular plot, hence the experimental results show only the effect of a given treatment in relation to the other treatments. The experimental data are interpreted in terms of the average individual beet under the conditions imposed. For convenience in visualizing the results, yields and sugar production are given with but one exception noted as acre values, assuming the stand as 100 percent. Significance of the individual experiments was determined by the z test.[6]

The sucrose and apparent coefficient-of-purity determinations are based upon the analysis of two 20-beet samples per plot. Each beet of the sample was cut in halves and one half of each beet discarded; from the halves retained, longitudinal sectors were rasped so that each beet in fair proportion to its size contributed fine pulp for a composite sample. The pulp was thoroughly mixed and used for sucrose and apparent coefficient-of-purity determinations. One portion of this composited pulp was digested by the Sachs le Docte cold-water method for determination of sucrose (*1*). The remainder of the pulp was used to furnish juice for refractometer readings of dry solids and for determination of sucrose in the juice, thus giving data from which the apparent coefficient of purity could be derived. The data for sucrose and apparent purity show, therefore, the quality of the average beet grown under the experimental conditions.

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[4] The data obtained at Twin Falls were on the actual-yield basis.

[5] By a "normally competitive beet" is meant a beet which has grown surrounded on all four sides by beets at approximately the right distance to conform to the requirements of the test. The average weight per beet, computed from the number of competitive beets harvested, and multiplied by the appropriate number of beets per acre (in the case of the 20- by 12-inch spacing series this is 26,136, and 19,602 beets for the 20- by 16-inch spacing series) has given the yield on the basis of a 100-percent stand under the conditions of this test.

[6] The data presented in these and succeeding tables have been analyzed according to the accepted statistical method by which the general variability between blocks may be eliminated and a valid estimate of error obtained. In the principle of the analysis of variance, the total variability is measured in sums of squares of deviations from the mean and certain fractions apportioned to soil heterogeneity between blocks, others to treatment or varietal effect, and the balance to unknown causes, ascribed as "error." The value of z is used as a convenient measure of the significance of the test for the attribute measured. z is one half the difference between the natural or Napierian logarithms of the two mean squares being compared. The value of z as calculated for the number of treatments and the degrees of freedom for error for the 5-percent point was 0.4064 and for the 1-percent point 0.5734. The formula used for calculation of the amount required for significance of differences between two means and between two general means is given as a footnote to table 3.

As will be seen from the listings given in tables 3 to 7, inclusive, the experimental work involved two space allotments, 20 by 12 inches and 20 by 16 inches. Hand and mechanical blockings are contrasted for each of these two spacings. The mechanically blocked plots with each of these space allotments were varied with respect to the time that the final thinning operation was performed, namely, some were thinned at once and in others thinning was delayed 12 days. In the 20- by 16-inch spacing series, plots were given 1, 2, or 3 cross cultivations for comparison with plots receiving no cross cultivations.

From this series of experiments, two types of findings result: (1) Those showing effects of treatment in a particular experiment and (2) those based on all of the experiments. The first give indications of the local responses to the treatments, whereas the consideration of the experiments in the eight localities as replicated indicates what the treatment may be expected to do as a general widely applied method. In the discussion of the results of these experiments which follows, both of these phases of the work are taken into consideration and the salient features of the tests pointed out.

SPACE-ALLOTMENT STUDIES

YIELD

Results from sugar beets spaced 20 by 12 and 20 by 16 inches under different conditions of treatment may be compared. In one case contrasts of hand-blocked plots differing in general treatment only by the space factor are available from comparing treatments 1 and 5 at the various places (table 3). At Grand Forks, Waseca, and Twin Falls the yields were significantly in favor of the closer spacing. At none of the other places was a significant difference obtained. Similarly, from treatments 2 and 6, plots that were mechanically blocked to these different space intervals in the row may be contrasted. At Grand Forks, Waseca, Rocky Ford, Sandy, and Twin Falls significantly higher yields came from the closer spacings. In the other cases no significant differences were found. A third set of comparisons is afforded by contrasting treatments 3 and 4, where thinning was delayed 12 days in each set of plots, the space interval in the row being the only variable. Significant differences in favor of closer spacing were obtained at Grand Forks, Waseca, Scottsbluff, and Sandy; at the other stations the differences were not significant.

TABLE 3.—*Yield of beets per acre obtained from field experiments in which hand blocking and mechanical cross blocking, delayed and normal thinning, and cross cultivating of beets were compared, 1932*

Treatment no.	Type of blocking	Thinning	Cross cultivations	Yield per acre at—								Average yield, all tests
				Grand Forks, Minn.	Waseca, Minn.	Scottsbluff, Nebr.	Fort Collins, Colo.	Rocky Ford, Colo.	Sandy, Utah	Twin Falls, Idaho	Chino, Calif.	
12- by 20-inch spacing series:				*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1	Hand	At once	0	13. 51	12. 03	16. 38	12. 34	10. 88	14. 44	13. 45	17. 34	13. 80
2	Mechanical	do	0	14. 80	13. 50	19. 21	10. 84	11. 49	17. 46	12. 17	19. 21	14. 84
3	do	Delayed 12 days.	0	13. 24	13. 02	20. 53	11. 51	10. 91	16. 47	11. 59	16. 94	14. 28
16- by 20-inch spacing series:												
4	do	do	0	10. 93	10. 90	18. 21	11. 02	10. 55	12. 89	12. 35	19. 49	13. 29
5	Hand	At once	0	11. 50	10. 68	17. 25	11. 54	10. 08	13. 42	10. 13	19. 89	13. 06
6	Mechanical	do	0	11. 53	10. 58	18. 82	10. 32	9. 67	13. 22	10. 04	17. 77	12. 74
7	do	do	1	12. 80	10. 74	18. 65	10. 52	12. 85	14. 41	9. 64	19. 38	13. 62
8	do	do	2	11. 79	11. 15	18. 42	10. 75	11. 22	14. 36	9. 59	20. 53	13. 48
9	do	do	3	12. 67	11. 29	17. 94	9. 96	10. 18	15. 45	8. 68	23. 38	13. 69
Standard error of mean				0. 4312	0. 4345	0. 5920	0. 3913	0. 6096	0. 8760	0. 4419	1. 6370	------
Difference required for significance				1. 2194	1. 2288	1. 6742	1. 1066	1. 7240	2. 4773	1. 2497	------	------
Standard error of general mean				------	------	------	------	------	------	------	------	[1]0.2765
Difference required for significance				------	------	------	------	------	------	------	------	[2].7819

[1] Derived from formula:

$$1/8\sqrt{(0.4312)^2+(0.4345)^2+(0.5920)^2+(0.3913)^2+(0.6096)^2+(0.8760)^2+(0.4419)^2+(1.6370)^2}=0.2765.$$

[2] Difference required for significance $=0.2765\times\sqrt{2}\times2=0.7819$.

If the experiments are considered as replicates of one large experiment and the average yield for all tests receiving treatment 1 are contrasted with the average yield of treatment 5, this comparison shows that for the entire test suggestively large but not significantly better yields come from the closer spacings. Significantly larger yields were shown in the comparisons of treatments 2 and 6, 3 and 4. It seems therefore safe to conclude that a 20- by 16-inch spacing may generally be expected to give a lower yield than a 20- by 12-inch spacing. It is clearly indicated from these tests that beet fields in which cultivation in two directions is to be made, the space allotments giving more beets per acre than the 20- by 16-inch spacing provides, must be used generally to avoid significant yield reductions.

QUALITY

In only 1 case (Scottsbluff, hand-blocked series) among the 3 sets of comparisons of space relations (table 4) was a significant difference in sucrose percentage obtained. This uniformity of performance is not entirely to be expected, in view of the indication of superior size of the beets existing, in general, in the tests. From the evidence, however, neither of the space allotments used can be said to have influenced sucrose percentage, and the same situation holds when the data from all the tests are considered.

TABLE 4.—*Sucrose in beets obtained from field experiments in which hand blocking and mechanical cross blocking, delayed and normal thinning, and cross cultivating of beets were compared, 1932*

Treatment no.	Type of blocking	Thinning	Cross cultivations	Sucrose in beets at—								Average percentage sucrose, all tests
				Grand Forks, Minn.	Waseca, Minn.	Scottsbluff, Nebr.	Fort Collins, Colo.	Rocky Ford, Colo.	Sandy, Utah	Twin Falls, Idaho	Chino, Calif.	
12- by 20-inch spacing series:				*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	Hand	At once	0	17.52	16.45	14.31	15.34	12.60	16.16	17.68	15.54	15.70
2	Mechanical	do	0	16.87	16.20	13.88	15.34	12.72	15.77	17.13	14.96	15.36
3	do	Delayed 12 days.	0	17.28	16.36	14.41	15.52	12.86	16.76	17.11	15.04	15.67
16- by 20-inch spacing series:												
4	do	do	0	16.95	16.08	14.36	15.28	12.90	15.87	16.90	14.86	15.40
5	Hand	At once	0	17.49	16.33	13.45	15.38	12.74	15.96	16.72	15.08	15.39
6	Mechanical	do	0	16.62	16.16	14.19	15.16	12.20	15.99	17.18	14.88	15.30
7	do	do	1	16.88	16.26	14.25	15.42	13.16	16.08	16.97	15.06	15.51
8	do	do	2	16.79	16.03	14.00	15.28	12.38	16.12	16.52	14.98	15.26
9	do	do	3	17.59	16.31	14.51	15.34	11.42	15.95	16.73	15.38	15.40
Standard error of mean				0.1738	0.1352	0.2283	0.1173	0.4008	0.4270	0.7044	0.3704	------
Difference required for significance				.4915	------	------	------	1.1330	------	------	------	------
Standard error of general mean				------	------	------	------	------	------	------	------	0.1305
Difference required for significance				------	------	------	------	------	------	------	------	.3691

The data for apparent coefficient of purity show in only one case a significant difference (table 5), hence space allotment cannot be said to have influenced this attribute to a determinable degree.

TABLE 5.—*Apparent coefficient of purity of beets obtained from field experiments in which hand blocking and mechanical cross blocking, delayed and normal thinning, and cross cultivating of beets were compared, 1932*

Treatment no.	Type of blocking	Thinning	Cross cultivations	Apparent coefficient of purity of beets at—								Average purity, all tests
				Grand Forks, Minn.	Waseca, Minn.	Scottsbluff, Nebr.	Fort Collins, Colo.	Rocky Ford, Colo.	Sandy, Utah	Twin Falls, Idaho	Chino, Calif.	
12- by 20-inch spacing series:												
1	Hand	At once	0	81.52	86.22	89.07	88.60	83.36	92.44	89.32	88.88	87.43
2	Mechanical	do	0	80.94	85.41	86.17	88.94	84.09	93.67	89.06	89.90	87.26
3	do	Delayed 12 days.	0	81.34	86.24	87.03	89.30	84.50	92.89	88.46	88.94	87.34
16- by 20-inch spacing series:												
4	do	do	0	81.06	85.84	87.33	89.18	83.84	93.17	90.48	88.68	87.45
5	Hand	At once	0	82.01	85.93	86.29	88.78	84.12	91.32	88.66	88.52	86.95
6	Mechanical	do	0	80.44	85.65	87.08	88.78	82.54	90.63	87.84	89.26	86.53
7	do	do	1	80.93	85.95	87.27	89.22	83.08	91.39	88.66	89.36	86.98
8	do	do	2	80.55	85.46	85.64	88.72	82.72	90.82	87.80	88.40	86.26
9	do	do	3	81.66	85.83	87.03	89.34	82.96	92.46	88.52	88.86	87.08
Standard error of mean				0.4912	0.2571	1.0690	0.3877	0.4830	1.2700	0.9910	0.6260	------
Difference required for significance				------	------	------	------	1.3660	------	------	------	------
Standard error of general mean				------	------	------	------	------	------	------	------	0.2805
Difference required for significance				------	------	------	------	------	------	------	------	.7932

SUGAR PRODUCED PER ACRE

When percentage of sucrose and apparent coefficient-of-purity values are not significantly different in a majority of the cases, the calculated sugar yields must then reflect largely the beet-yield differences obtained. Such is the case in this set of tests and the differences obtained in sugar yields are therefore not discussed in detail. Considering the averages of the tests as a unit, the yields of gross and indicated available sugar (tables 6 and 7) show that the consistently larger yields have been obtained from the closer spaced beets. Comparing treatments 1 and 5, 2 and 6, and 3 and 4, the differences obtained are 391 pounds, 766 pounds, and 376 pounds gross sugar yield, respectively, in favor of the closer spaced beets (table 6).

TABLE 6.—*Gross sugar yield per acre obtained from field experiments in which hand blocking and mechanical cross blocking, delayed and normal thinning, and cross cultivating of beets were compared, 1932*

Treatment no.	Type of blocking	Thinning	Cross cultivations	Yield of gross sugar per acre [1] at—								Average gross sugar yield, all tests
				Grand Forks, Minn.	Waseca, Minn.	Scottsbluff, Nebr.	Fort Collins, Colo.	Rocky Ford, Colo.	Sandy, Utah.	Twin Falls, Idaho	Chino, Calif.	
12- by 20-inch spacing series:				*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1	Hand	At once	0	4, 726	3, 961	4, 696	3, 784	2, 814	4, 661	4, 744	5, 393	4, 918
2	Mechanical	do	0	4, 991	4, 375	5, 333	3, 321	2, 946	5, 501	4, 166	5, 737	5, 143
3	do	Delayed 12 days.	0	4, 577	4, 265	5, 918	3, 570	2, 814	5, 166	3, 935	5, 076	4, 996
16- by 20-inch spacing series:												
4	do	do	0	3, 701	3, 503	5, 234	3, 364	2, 746	4, 084	4, 226	5, 823	4, 620
5	Hand	At once	0	4, 005	3, 491	4, 651	3, 549	2, 632	4, 277	3, 417	5, 996	4, 527
6	Mechanical	do	0	3, 822	3, 417	5, 323	3, 130	2, 358	4, 220	3, 352	5, 309	4, 377
7	do	do	1	4, 312	3, 498	5, 309	3, 242	3, 476	4, 604	3, 266	5, 845	4, 731
8	do	do	2	3, 955	3, 575	5, 159	3, 280	2, 797	4, 628	3, 171	6, 131	4, 621
9	do	do	3	4, 450	3, 689	5, 209	3, 046	2, 350	4, 918	2, 884	7, 202	4, 779
Standard error of mean				148. 63	142. 86	178. 90	110. 28	223. 61	271. 38	203. 31	313. 00	
Difference required for significance				420. 33	404. 01	505. 93	311. 87	632. 33	767. 46	574. 96		
Standard error of general mean												73. 87
Difference required for significance												208. 90

[1] Obtained by multiplying yield by sucrose percentage, and averaging individual plot values for sugar production, hence differ slightly from product of means given in this table.

TABLE 7.—*Indicated available sugar yield per acre obtained from field experiments in which hand blocking and mechanical cross blocking, delayed and normal thinning, and cross cultivating of beets were compared, 1932*

Treatment no.	Type of blocking	Thinning	Cross cultivations	Yield of indicated available sugar per acre [1] at—								Average indicated available sugar yield, all tests
				Grand Forks, Minn.	Waseca, Minn.	Scottsbluff, Nebr.	Fort Collins, Colo.	Rocky Ford, Colo.	Sandy, Utah	Twin Falls, Idaho	Chino, Calif.	
12- by 20-inch spacing series:				*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1	Hand	At once	0	3, 855	3, 415	4, 177	3, 352	2, 352	4, 308	4, 236	4, 793	3, 811
2	Mechanical	do	0	4, 039	3, 736	4, 599	2, 952	2, 477	5, 172	3, 708	5, 154	3, 980
3	do	Delayed 12 days.	0	3, 718	3, 679	5, 153	3, 186	2, 374	4, 812	3, 472	4, 514	3, 864
16- by 20-inch spacing series:												
4	do	do	0	3, 001	3, 008	4, 585	2, 999	2, 306	3, 814	3, 824	5, 174	3, 589
5	Hand	At once	0	3, 284	3, 000	4, 016	3, 150	2, 218	3, 906	3, 035	5, 331	3, 493
6	Mechanical	do	0	3, 074	2, 926	4, 636	2, 778	1, 946	3, 823	2, 945	4, 749	3, 360
7	do	do	1	3, 491	3, 006	4, 633	2, 890	2, 891	4, 212	2, 894	5, 231	3, 656
8	do	do	2	3, 185	3, 056	4, 421	2, 909	2, 318	4, 201	2, 784	5, 425	3, 537
9	do	do	3	3, 633	3, 166	4, 538	2, 723	1, 948	4, 559	2, 548	6, 397	3, 689
Standard error of mean				127. 00	120. 88	166. 60	97. 04	174. 87	264. 68	158. 79	273. 00	
Difference required for significance				359. 16	341. 85	471. 40	274. 40	494. 53				
Standard error of general mean												64. 80
Difference required for significance												183. 25

[1] Obtained by multiplying gross sugar per acre by apparent coefficient of purity.

EFFECT OF TYPE OF BLOCKING

YIELD

When results obtained from the plots of hand-blocked beets spaced 20 by 12 inches are compared with those beet plots that were mechanically blocked, treatments 1 and 2, it is seen that in the Grand Forks, Waseca, Scottsbluff, and Sandy tests the yields were significantly in favor of the mechanical blocking (table 3). At Fort Collins and Twin Falls the hand-blocked plots were significantly the better, and at Rocky Ford and Chino the results were not significantly different. Contrasting treatments 5 and 6, in the 20- by 16-inch spacing series, the hand-blocked beet plots produced significantly better yields in the Fort Collins test. At none of the other places were significant differences obtained.

Considering the experiments at all places as a replicated test, the mechanically blocked beet plots produced on the average significantly better yields than the hand-blocked plots in the 20- by 12-inch spacing series. In the 20- by 16-inch spacing series there was no significant difference in yield between the two methods of blocking beets.

QUALITY

In only 3 cases out of the 16 in the 2 sets of comparison treatments, 1 and 2, 5 and 6, were significant differences in percentage of sucrose obtained. Two of these differences were in favor of the hand-blocked beet plots, one was in favor of the mechanically blocked beet plots. No significant differences were obtained in the other tests. When the averages of the comparable tests are considered, the type of blocking employed in this set of experiments cannot be said to have influenced the percentage of sucrose.

In only 3 cases out of the 16 in the 2 sets of the comparisons cited were significant differences obtained in apparent coefficient of purity, these being in favor of the hand-blocked beet plots. It must therefore be concluded that in general the apparent coefficient of purity of the beets was not materially affected by the method of blocking.

SUGAR PRODUCED PER ACRE

In gross sugar production, the average difference between the hand-blocked and mechanically blocked plots in the 20- by 12-inch spacing series is 225 pounds in favor of the latter. This significantly large difference may be attributed almost entirely to the greater beet yield. In the 20- by 16-inch spacing series, the average difference of 150 pounds in favor of the hand-blocked plots is less than the minimum level of significance.

Comparing the averages of all tests for differences in yield of indicated available sugar per acre, the mechanically blocked beet plots produced 169 pounds more sugar in the 20- by 12-inch spacing series, and in the 20- by 16-inch spacing series comparison the hand-blocked beet plots produced 133 pounds more sugar per acre. The differences in both cases were too small to be considered significant.

EFFECT OF DELAYING THINNING AFTER COMPLETION OF THE BLOCKING OPERATION

There are instances when delaying the thinning of plants after they have been blocked is necessary. In some instances this delay in thinning the beets promptly after the completion of the operation of blocking when performed with a machine may be due to insufficient labor; in others prompt thinning of the blocked plants is inadvisable because of the seedling diseases. To determine the effect such a delay produces on the yield and quality of beets, a comparison was made between beet plots mechanically blocked and thinned at once and those in which thinning was delayed approximately 12 days. The tests were carried on with both spacing intervals used in these tests. Comparisons of the results from treatments 2 and 3 in the 20- by 12-inch spacing series and 4 and 6 in the 20- by 16-inch spacing series permit the evaluation of the effect of this delay.

YIELD

From the comparisons of treatments 2 and 3, it was found that thinning the beets as soon as blocking was completed produced significantly better yields at Grand Forks, there being no significant differences in the tests at other places. When treatments 4 and 6 are compared a significantly higher yield was obtained in Twin Falls plots in which thinning was delayed following blocking. There were no significant differences at other places. In line with these findings, the general analysis of the practice permitted by considering the entire series of tests as a unit shows no significant benefits from the practice so far as yields were concerned.

QUALITY

The percentage of sucrose differed so slightly in the two sets of comparisons that no significant effect was shown. When the average of all tests is considered, the difference in favor of delayed thinning is 0.31 percent sucrose in the 20- by 12-inch spacing series and 0.01 percent sucrose in the 20- by 16-inch spacing series, neither difference being significant.

Similarly, no significant effect upon the apparent coefficient of purity was found. When the average of all tests is considered, a small but not significant difference of 0.08 is obtained in favor of the delayed thinning plots in the 20- by 12-inch spacing series. In the 20- by 16-inch spacing series the difference of 0.92 is significantly large, but in view of the fact that 7 of the 8 tests showed no significant *z* value, it appears probable that these results are due to chance rather than being due to treatment.

SUGAR PRODUCED PER ACRE

Comparing the averages of all treatments, in the 20- by 12-inch spacing series, no significant differences were found to indicate that the delay in thinning influenced the amount of gross sugar produced per acre. In the 20- by 16-inch spacing series a difference, 243 pounds, large enough to be significant was found in favor of the delayed thinning of beets. In view of the absence of decisive effects in yield and sucrose, the importance of this is minimized.

In pounds of indicated-available sugar, neither method of thinning beets resulted in significant differences between the treatments compared in the 20- by 12-inch spacing series. In the 20- by 16-inch spacing series, the plots in which thinning was delayed outyielded the beet plots thinned at once following blocking by 229 pounds. Although this difference is above the minimum level of significance, it is not considered clear-cut evidence of benefit attributable to delay in thinning, since in a majority of the tests the values for yield, percentage of sucrose, and apparent coefficient of purity were not found significantly affected by treatment.

The importance of the findings from these tests comes largely from the demonstration of no significant effect on yield resulting from delay in thinning following mechanical blocking. In commercial practice the mechanical blocking of the field at one time and considerably in advance of thinning operations is necessary. These results indicate that no detrimental effects are to be expected by blocking a number of days ahead of the thinning, provided that sufficient moisture is present in the soil to fully meet the needs of the small beet plants. It has been noticed occasionally that when cross blocking is done before beet seedlings have had an opportunity to become fully established the resulting stand was reduced greatly. The cause ascribed to this condition is the increased aeration of the soil as a result of the mechanical-blocking operation and an increased soil-moisture loss. Due cognizance should therefore be taken of the moisture situation in the soil to determine when the beet stand may safely be cross blocked.

CROSS-CULTIVATION TESTS

YIELD

Comparisons to determine results of cultivations given across the rows in addition to the standard cultivations along the rows are shown in tables 3 to 7 as treatments 6, 7, 8, and 9. The number of cross cultivations was 0, 1, 2, and 3. At Grand Forks, Rocky Ford, and Chino, one or more cross cultivations produced an increase in weight of the average individual beet large enough to be significant. There were no significant differences in four of the tests while in the fifth test (Twin Falls) cross cultivations significantly decreased the individual beet size. All tests considered, the average yields on a normally competitive beet basis for the plots cross cultivated 1 and 3 times show significant yield increases as compared to the plots which had not been cross cultivated. The plots which received 2 cross cultivations show a yield difference of 0.74 ton in favor of cross cultivation, which difference while suggestively large fails to reach the figure of 0.78 ton required for significance.

QUALITY

For the factors, percentage of sucrose, and apparent coefficient of purity, no significant effects ascribable to cross cultivations were found. Apparently under the conditions of these tests, in general, the quality of the beet was not materially influenced. In one instance (Rocky Ford) with an increase in number of cross cultivations a significant decrease in percentage of sucrose occurred.

SUGAR PRODUCTION PER ACRE

In pounds of gross sugar per acre, when the average of all tests is considered, plots which received 1, 2, and 3 cross cultivations produced significantly larger sugar yields than the comparison plots which had not been cross cultivated. The same trend of results was obtained in yields of indicated available sugar per acre. These results are attributed to the effect of the cross cultivations in yield; since, considering the experiment as a unit, no significant differences in sucrose percentages and apparent coefficients of purity were found. It is to be noted that the general average of yields from the cross-cultivated plots falls significantly below the yield of mechanically blocked plots which had 12-inch spacing instead of 16-inch spacing. This has been discussed on page 12.

DISCUSSION

The results obtained from tests in farmers' fields and in the intensive agronomic tests conducted in 1931 and 1932 represent widespread tests under conditions that are considered fairly typical of those to be encountered in fields of sugar beets of fairly good stand and of good seed-bed condition. In only 1 case of 12 tests carried on in farmers' fields in 1931 and 1932 was a significant increase in actual yield in favor of hand blocking obtained. In the intensive agronomic tests, where judgment was based primarily upon the weight of the average individual beet normal for the conditions of the experiment, the results were in general significantly in favor of the machine operations in the tests where 20- by 12-inch spacing was used. With the 20- by 16-inch spacing used in some tests, neither method had significant advantage over the other. Outstanding differences in quality of the beets obtained by one method of blocking or the other were not found. These experiments had as their purpose critical evaluation of the machine method in comparison with standard practice. Slight differences in stand of beets in favor of hand blocking apparently are compensated. The conclusion seems safe that, so far as the experimental work has gone, the mechanical-blocking operation, if carefully done on fields where the stand is adequate and the seed bed suitable, is entirely practicable and instead of being detrimental to yield may improve yields.

In the tests in 1931, cross cultivation was found of value in the field in which the weed factor was important. This relation was confirmed in the 1932 tests. The experiments in which gain was shown decisively were the ones in which far better weed control was obtained as a result of cultivation in two directions. Local considerations will largely influence the adoption of cross cultivation. Because of the handicap which the wide spacing in the row imposes, the measure cannot be given general endorsement. If space allotments can be found that obviate this handicap, then the advantage of superior weed control will doubtless make it a very desirable method of crop handling.

In the period previous to 1930, mechanical blocking of beets had been considered primarily as an emergency measure to be used in fields where blocking and thinning for one reason or another had been unduly delayed. As the method came into wider use in some sections, concern was expressed that it might cause serious yield reductions. These results, so far as they are applicable, should encourage further extension and trial of the method in those fields where the conditions warrant. The method has manifest advantages and may be important in reducing production costs. The efficiency likely to result from its adoption will be especially important with large acreages where, at present, rapid handling of the thinning operations is difficult to attain.

In areas where beet stands are irrigated up, objection has been raised to the machine cross-blocking method on the grounds that the irrigation furrow and field laterals make it difficult to obtain satisfactory work. Experience in the irrigated section has shown that the field laterals can be plowed in to obviate any difficulty from this source. The irrigation furrows used in bringing up the seed may be leveled by cultivation at the time of the first lengthwise cultivation of the unthinned plants. When a crusted or cloddy condition of the soil is encountered, this should be corrected by the use of a roller driven diagonally to the direction of the planted row. Following this, cross blocking with the cultivator equipment can readily be accomplished. It should be pointed out that fields must have a reasonably clean surface free from residues of preceding crops if clogging of the cultivator tools used in cross blocking the rows and resulting reduction in stand are to be avoided.

Since the chosen spacing interval is fixed for the mechanically cross-blocked beets, this method should, under careful supervision, result in more satisfactory work from inefficient thinners who are inclined to leave too wide a space between beets. It has also been noted that the laborer has more opportunity to do selective thinning where the blocks are established for him. Judging from experimental and field results, selective thinning of uniformly spaced beets to leave the sturdy plants frequently shows definite gains in yields.

The fact that the laborers perform the job of thinning work more rapidly in mechanically cross-blocked fields was evidenced by the increased acreage handled per man. The labor required to mechanically block and hand thin beets was 30 to 40 percent less than the labor required to hand block and thin beets under parallel conditions. With hand blocking and thinning, it ordinarily has been desirable to space the sugar-beet plantings so that the beets would not become large and spindling before thinning was completed. More rapid completion of the thinning operations made possible by mechanical blocking permits a grower to plant his entire acreage at one planting instead of using two or three successive plantings. Aside from the possible extra cost entailed in the additional preparation of the seed bed for each successive planting, there is usually a significant difference in tonnage and sugar production per acre in favor of the early over late plantings. No value was found to come from delaying thinning operation for 12 days after the mechanical blocking was given. On the other hand, no decrease in yield or quality of the beets was found, so that fields may under ordinary conditions be machine blocked considerably ahead of the thinning operations without detriment.

The results of the cross-cultivation experiments conducted in 1931 indicate that beet yields may under some conditions be influenced favorably by the more effective weed control brought about by the cross cultivation given. In the intensive tests where the effect of varying numbers of cross cultivations given the beets was compared, the results are not strictly applicable to field conditions inasmuch as in 7 of the 8 tests competitive beets alone were harvested. This was done so as not to introduce certain other fluctuating variables into the test. It is known that cross cultivating affects the percentage of stand in proportion to the care used in cultivating the beet crop. The results, obtained on the normally competitive beet basis, evaluate only the effect which varying numbers of cultivations have on the performance of individual beets. The cases where increased yield was shown may definitely be assigned to more effective weed control. This was especially noticeable in the Chino plots where a heavy infestation of bindweed occurred, and where an appreciable increase in size of individual beets resulted as the number of cross cultivations increased.

Other benefits have been attributed to the cross-cultivation practice. In commercial fields where cross cultivation was practiced, since a larger space allotment was made for each individual plant, the savings on labor required to thin an acre of beets were found to be greater for large commercial acreages than those reported in this circular for mechanically blocked beets. In fields cross blocked to wide spaces to provide for cross cultivation, thinning was speeded up greatly, often a twofold output of acreage thinned per day per adult worker being secured. It has been reported (*6*) that most of the hand labor required for seasonal care of the beet crop in this area has been obtained from local sources. The lessened labor requirements brought about by mechanical blocking and cross cultivating beets are held as being responsible for this condition. Sugar-beet growers in Minnesota who have used the cross-cultivating method on approximately 35 percent of the 1931 sugar-beet acreage and 40 percent of the sugar-beet acreage in 1932 made an appreciable saving in the contract hand-labor costs.[7] In those cross-cultivated sugar-beet fields where cultivation was performed, hand-hoeing was seldom necessary. A lessened tendency for beets to wilt in hot weather was observed. Fewer large cracks developed in the soil in the cross-cultivated fields in dry weather as compared to the beet fields handled in the ordinary manner.

The indications from the results reported in this circular are that narrower row widths and closer spacings in the row than are now used in cross-cultivated fields may be found necessary to avoid the yield reduction likely to come with the lessened number of plants per acre. An approach to the present space allotment of approximately 240 square inches per plant used as a standard in the ordinary sugar-beet practice appears desirable if cross cultivating is to be used generally. Tests reported here demonstrate advantages resulting from the more effective weed control. However, before cross cultivating can be generally recommended as a method, it will be necessary to find suitable space allotments per plant, which are not likely to involve yield decreases.

SUMMARY

Mechanical and hand blocking of beets were compared in a number of experiments conducted in several States. The mechanically blocked sugar-beet plots showed generally favorable yield results when a space allotment per plant approaching the standard (240 square inches) was used. A chart showing proper spacing of tools on the cultivator to obtain a certain percentage stand of blocked beets is presented. The experimental results of the 2 years indicate that response to cross cultivation is conditioned by the importance of the weed factor and that the cultivations in themselves did not strongly influence yield or quality.

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